

A HEAT SINK APPARATUS THAT PROVIDES ELECTRICAL ISOLATION FOR INTEGRALLY SHIELDED CIRCUIT

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FIELD OF THE INVENTION

The present invention relates generally to the field of microwave circuits, and more particularly to integrated thick film RF and microwave microcircuit modules, and
10 even more particularly to the dissipation of heat generated by such modules.

BACKGROUND OF THE INVENTION

15 Microwaves are electromagnetic energy waves with very short wavelengths, typically ranging from a millimeter to 30 centimeters peak to peak. In high-speed communications systems, microwaves are used as carrier signals for sending information from point A to point B. Information carried by microwaves is transmitted, received, and processed by microwave circuits.

20 Packaging of radio frequency (RF) and microwave microcircuits has traditionally been very expensive and has required very high electrical isolation and excellent signal integrity through gigahertz frequencies. Additionally, integrated circuit (IC) power densities can be very high. Microwave circuits require high frequency electrical isolation between circuit components and between the circuit itself and other electronic circuits.
25 Traditionally, this need for isolation was resulted in building the circuit on a substrate, placing the circuit inside a metal cavity, and then covering the metal cavity with a metal plate. The metal cavity itself is typically formed by machining metal plates and then connecting multiple plates together with solder or an epoxy. The plates can also be cast, which is a cheaper alternative to machined plates. However, accuracy is sacrificed with
30 casting.

One problem attendant with the more traditional method of constructing microwave circuits is that the method of sealing the metal cover to the cavity uses conductive epoxy. While the epoxy provides a good seal, it comes with the cost of a greater electrical resistance, which increases the loss in resonant cavities and increases leakage in shielded cavities. Another problem with the traditional method is the fact that significant assembly time is required, thereby increasing manufacturing costs.

Another traditional approach to packaging RF/microwave microcircuits has been to attach gallium arsenide (GaAs) or bipolar integrated circuits and passive components to thin film circuits. These circuits are then packaged in the metal cavities discussed above. Direct current feed-through connectors and RF connectors are then used to connect the module to the outside world.

Still another method for fabricating an improved RF microwave circuit is to employ a single-layer thick film technology in place of the thin film circuits. While some costs are slightly reduced, the overall costs remain high due to the metallic enclosure and its connectors, and the dielectric materials typically employed (e.g., pastes or tapes) in this type of configuration are electrically lossy, especially at gigahertz frequencies. The dielectric constant is poorly controlled at both any specific frequency and as a function of frequency. In addition, controlling the thickness of the dielectric material often proves difficult.

A more recent method for constructing completely shielded microwave modules using only thick film processes without metal enclosures is disclosed by Lewis R. Dove, et al. in U.S. Patent No. 6,255,730 entitled "Integrated Low Cost Thick Film RF Module".

Heat dissipation from integrated circuits and other devices in high frequency microcircuits is an especially difficult problem. In order to increase heat transfer from those microcircuit devices having high heat dissipation, the devices are often attached directly to heat sinks, also referred to as heat spreaders or heat pedestals. However, lower thermal conductivity often precludes attachment to the organic or ceramic substrate typically used in such circuits.

Thus, when high power integrated circuits or other high power devices are used in an integrated Thick Film Microwave Module, a hole is usually cut in the ceramic

substrate to accommodate a metallic heat sink. This cut breaks the electrical isolation provided by a ground plane typically located on top of the substrate. This break in electrical isolation is undesirable for microwave applications as they typically require very high electrical isolation. Breaks in the ground plane result in the radiation of
5 electromagnetic energy.

Thus, there is a need for a means of attaching heat sinks to devices in high frequency microcircuits without compromising the electrical isolation of the module.

SUMMARY OF THE INVENTION

In one embodiment, a heat sink apparatus that provides electrical isolation for an integrally shielded, electronic circuit comprises a substrate having a first hole extending between a first and second sides of the substrate, a conductive layer attached to the second side, an electrically and thermally conductive heat sink having a protrusion, wherein the heat sink is attached to the first side of the substrate, and an electrically conductive plate having a second hole extending through the plate. The protrusion extends through the first hole and has a surface located at substantially the same level as that of the conductive layer. An electronic component is attachable to the protrusion surface. The plate is electrically coupled to the conductive layer and to the protrusion surface such that open space between the protrusion and the conductive layer is covered by electrically conducting area of the plate.

In another embodiment, a heat sink apparatus that provides electrical isolation for an integrally shielded, electronic circuit comprises a substrate having a first hole extending between a first and second sides of the substrate, a conductive layer attached to the second side, and an electrically and thermally conductive heat sink having a protrusion. The heat sink is attached to the first side of the substrate. The protrusion extends through the first hole and has a surface located at substantially the same level as that of the conductive layer. An electronic component larger than the protrusion surface is electrically connectable to the conductive layer and is electrically and thermally connectable to the protrusion surface such that open space between the protrusion and the conductive layer is covered by the electronic component.

Other aspects and advantages of the present invention will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings provide visual representations which will be used to more fully describe the invention and can be used by those skilled in the art to better understand it and its inherent advantages. In these drawings, like reference numerals identify corresponding elements.

Figure 1 is a drawing of a heat sink apparatus that provides electrical isolation for an integrally shielded, electronic circuit as described in various representative embodiments consistent with the teachings of the invention.

Figure 2 is a drawing of a top view of the conducting plate as described in various representative embodiments consistent with the teachings of the invention.

Figure 3 is a drawing of another heat sink apparatus that provides electrical isolation for an integrally shielded, electronic circuit as described in various representative embodiments consistent with the teachings of the invention.

Figure 4 is a drawing of a top view of the electronic component and protrusion as described in various representative embodiments consistent with the teachings of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in the drawings for purposes of illustration, the present patent document relates to a novel heat sink apparatus that provides electrical isolation for an electronic circuit. Previous heat sinks have resulted in imperfect encapsulation and thus allowed electromagnetic signals, especially those at high-frequencies, to radiate from the enclosures in which the circuits are integrally shielded.

In the following detailed description and in the several figures of the drawings, like elements are identified with like reference numerals.

Figure 1 is a drawing of a heat sink apparatus **100** that provides electrical isolation for an integrally shielded, electronic circuit **105** as described in various representative embodiments consistent with the teachings of the invention. In Figure 1, the electronic circuit **105** is a microcircuit **105**. An electronic component **110** which could be, for example, an integrated circuit **110** is attached to a heat sink **115** via conductive adhesive **120**, solder paste **120**, or the like. The heat sink **115** is also often referred to as a heat spreader **115** and as a heat pedestal **115**, the term heat pedestal **115** referring to a protrusion **125** or pedestal **125** extending from the body of the heat sink **115**. The electronic component **110** is attached to the protrusion **125** at a protrusion surface **130**. The heat sink **115** is attached to a first side **136**, also referred to herein as a bottom side **136**, of a substrate **135**. The substrate **135** has a first hole **140** extending from the first side **136** through to a second side **137**, also referred to herein as a top side **137**, of the substrate **135**. Conductive layers **145** separated by dielectric layers **150** are used to electrically couple the electronic component **110**, via wires **155** bonded to the electronic component **110** and the conductive layers **145**, to other parts of the microcircuit **105**. Various structures of the microcircuit **105**, including the conductive layers **145** and dielectric layers **150**, are typically created using conventional thin film deposition techniques or conventional thick film screening techniques. The conductive layer **145** attached to the top side **137** of the substrate **135** is typically a ground plane and electrically coupled to the heat sink **115** through a conducting via, not shown in the drawings. A conducting lid **160** provides electrical shielding of the microcircuit **105** on the top side of the microcircuit **105**. Due to imperfect fabrication techniques, a gap **165**

or open space **165** exists between the protrusion **125** of the heat sink **115** and the conductive layer **145** attached to the top side **137** of the substrate **135** through which electromagnetic signals can radiate. This open space **165** is closed, thus preventing radiation of the electromagnetic signals through the open space **165**, via attachment of an electrically conductive plate **170** between the protrusion **125** and the conductive layer **145** attached to the substrate **135**. The conductive plate **170** is typically attached via a conventional conductive adhesive **120** or solder **120**.

Figure 2 is a drawing of a top view of the conductive plate **170** as described in various representative embodiments consistent with the teachings of the invention. The conductive plate **170** comprises an electrically conductive area **175** and an opening **180** in the plate **170**. The opening **180** is also referred to herein as a second hole **180**. Referring to Figure 1, the electronic component **110** is attached to the protrusion **125** of the heat sink **115** within the opening **180** of the plate **170**. The conductive area **175** of the plate **170** is attached to the substrate **135** with the conductive area **175** of the electrically conductive plate **170** covering the open space **165** and preventing radiation of the electromagnetic signals through the open space **165**.

In the embodiments of Figures 1 and 2, the plate **170** could be fabricated as a thin piece of conductive material, as for example Kovar, to bridge the gap between the so-called top-bottom ground plane, identified herein as the conductive layer **145** attached to the top side **137** of the substrate **135**, of an integrated thick film microwave module and the heat sink **115**. This plate **170** could be soldered or attached with a conductive adhesive **120**. If solder **120** is used, the plate **170** could be fabricated with a solder preform **120**. The integrated circuit **110** or other electronic component **110** is then attached to the protrusion **125** of the heat sink **115** using solder **120** or a conductive adhesive **120**. The integrated circuit **110** is located within the opening **180** in the plate **170**. The plate **170** and grounded heat sink **115** provide electrical continuity for the module's ground.

Figure 3 is a drawing of another heat sink apparatus **100** that provides electrical isolation for an integrally shielded, electronic circuit **105** as described in various representative embodiments consistent with the teachings of the invention. In Figure 3, the electronic circuit **105** is a microcircuit **105**. An electronic component **110** which

could be, for example, an integrated circuit **110** is attached to a protrusion **125** of a heat sink **115** typically via conductive adhesive **120**, solder paste **120**, or the like. The electronic component **110** is attached to the protrusion **125** at protrusion surface **130**. The heat sink **115** is attached to the bottom side **136** of the substrate **135**. The substrate **135** has a first hole **140** extending from the first side **136** through to the top side **137**, of the substrate **135**. Conductive layers **145** separated by dielectric layers **150** are used to electrically couple the electronic component **110**, via wires **155** bonded to the electronic component **110** and the conductive layers **145**, to other parts of the microcircuit **105**. Various structures of the microcircuit **105**, including the conductive layers **145** and dielectric layers **150**, are typically deposited using conventional thin film techniques or screened on using conventional thick film techniques. The conductive layer **145** attached to the top side **137** of the substrate **135** is typically a ground plane and electrically coupled to the heat sink **115** through a conducting via, not shown in the drawings. The conducting lid **160** provides electrical shielding of the microcircuit **105** on the top side **137** of the microcircuit **105**. Due to imperfect fabrication techniques, the gap **165** or open space **165** exists between the protrusion **125** of the heat sink **115** and the conductive layer **145** attached to the top side **137** of the substrate **135** through which electromagnetic signals can radiate. This open space **165** is closed, thus preventing radiation of the electromagnetic signals through the open space **165**, by constructing the protrusion **125** of the heat sink **115** to be smaller than the electronic component **110** and then attaching the electronic component **110** such that it overlaps the open space **165** electrically connecting the protrusion **125** and the conductive layer **145** attached to the substrate **135**.

Figure 4 is a drawing of the top view of the electronic component **110** and protrusion **125** as described in various representative embodiments consistent with the teachings of the invention. Referring to Figure 3, the electronic component **110** is attached to the protrusion **125** of the heat sink **115**. The electronic component **110**, which is slightly larger than the protrusion surface **130**, is also attached to the conductive layer **145** attached to the substrate **135**, thereby covering the open space **165** and preventing radiation of the electromagnetic signals through the open space **165**.

For the embodiments of Figures 3 and 4, the protrusion **125** of the heat sink **115** is designed to be slightly smaller than the integrated circuit **110**. The back of the

integrated circuit is used to bridge the gap **165** between the microcircuit module's **105** so-called top-bottom ground plane, identified herein as the conductive layer **145** attached to the top side **137** of the substrate **135**, and the protrusion **125** of the heat sink **115**. The integrated circuit **110** is soldered or attached with a conductive adhesive **120** to both the
5 protrusion **125** of the heat sink **115** and the top-bottom ground plane on the microcircuit module's **105** substrate **135**. This attachment can be performed by carefully controlling the height of the top of the protrusion **125** of the heat sink **115** in relation to the top of the substrate **135** by using die attach material to take up any difference. This embodiment eliminates the plate **170** and permits shorter wire/ribbon bonds to be used to connect the
10 integrated circuit die **110** to the microcircuit module's **105** conductive layers **145** which is an important consideration for many high frequency applications so as to minimize the parasitic inductance associated with the die bonding.

Thus, preferred embodiments of the heat sink apparatus **100** provide the ability to electrically isolate microcircuits **105** by covering open spaces **165** between the
15 protrusions **125** of heat sinks **115** and the holes **140** in the substrates **135** through which they pass. Thereby, leakage of electromagnetic radiation around the heat sink attachment is prevented.

While the present invention has been described in detail in relation to preferred embodiments thereof, the described embodiments have been presented by way of
20 example and not by way of limitation. It will be understood by those skilled in the art that various changes may be made in the form and details of the described embodiments resulting in equivalent embodiments that remain within the scope of the appended claims.